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FABRICATION OF ULTRAFINE BERYLLIUM WIRE

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RESEARCH AND DEVELOPMENT

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ABSTRACT

The results of the third and fourth month's work which is directed toward development of a process for the production of ultrafine beryllium wire by warm drawing techniques are described. Using conventional drawing techniques, a minimum beryllium wire diameter of 0.001420 inch was attained.

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FABRICATION OF ULTRAFINE BERYLLIUM WIRE

I. INTRODUCTION

The object of this project is to develop techniques for drawing QMV® beryllium wire to 0.001-inch diameter, to establish the optimum properties of the wire, and to furnish 100 feet of the best product produced. Previously, The Brush Beryllium Company successfully developed techniques for fabrication of beryllium wire at sizes down to 0.00477 inch under two Navy contracts: Nos. NOas 59-6030-c[1] and NOas 60-6108-c.[2]

The work reported here is essentially a continuation of the previous programs.

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II. EXPERIMENTAL WORK AND RESULTS

A. Procedure

As stated previously, [3] the procedure was changed to include drawing the wire to 0.001-inch diameter, or as small as possible, using the general drawing techniques established in other work. [2] This practice consists of reducing bare beryllium wire at 800° F in 10% reduction of area passes at a speed of 13 - 15 feet per minute using the standard moly-disulfide lubrication system.

The starting beryllium wire used in the following draw runs was two coils of 0.00477-inch diameter by 50 feet long from Lot No. 209-2-6295. [3]

In order to facilitate the handling of the small size wire and to achieve the required reductions, additional tools and equipment were added to the existing wire draw bench. One set of 28 diamond draw dies having a 10% reduction schedule was obtained between 0.00407 and 0.00098 inch diameters. All other dies necessary to process other starting diameters were on hand. Pay-off and powered take-up spool assemblies were added to the wire draw bench. The pay-off spool was positioned up-stream from the pre-heat furnace and provided an adequate means to introduce the wire to the drawing line. Space was provided between the pay-off spool and the pre-heat furnace to accommodate a simple continuous lubricator. The take-up spool is powered by a fractional h.p. motor-Zero-Max variable speed drive combination.

This assembly features a 4 oz. minimum-torque slip clutch between the Zero-Max and the reel. The take-up reel is positioned 5 feet downstream from the capstan. At this distance it was found that the wire level winds itself in a suitable manner eliminating any need for a level-wind mechanism. The reels are standard 1 3/4 inch O.D. x 3 inches long, made of plastic, and were obtained from the Boonton Molding Company of New Jersey.

Other auxiliary equipment was found necessary for cleaning and inspection of the product and dies below the nominal size of 0.004 inches. Inspection of dies and product is done under a microscope, 15, 45, or 90X, having the proper mounting and

lighting fixtures. In-process product inspection and die threading were made easier by using a standard 5-inch diameter portable magnifier. The die cleaning operation uses a Branson "Sonogen" ultrasonic generator with a solution of water plus a porcelain and metal cleaner as the bath. Together with these tools, the general "hand" technique of processing difficult small diameter die problems was thoroughly demonstrated by the Indiana Wire Die Company and has been used quite extensively during this program.

B. Warm Drawing Results

The first warm draw run (Table I) brought into focus a minor lubricating problem and the importance of proper die handling facilities and techniques. Although little trouble was experienced until the 0.002053-inch diameter die, it was noted that a lubricant build-up occurred in the tapered section of the die during the draw run. This build-up increased in quantity as the die size decreased. The difficulty of removing the lubricant also increased as the die size decreased. Rethreading dies having this build-up in the taper was impossible. This situation was eliminated with the addition of the ultrasonic cleaner and thinning the standard lubricant with water at a ratio of 15 to 1.

The failures shown in Table I for the first run were thought to be caused by improper lubrication, especially between 0.002053 and 0.001848-inch die sizes. The failures noted below 0.001663-inch die size were caused partly by improper handling. The draw run was stopped at 0.001497-inch die size, because a dirty die prevented all threading attempts.

The second draw run again processed without difficulty until the 0.002164-inch die was reached. Repeated tensile failures of wire at the pay-off reel were experienced, scrapping out the entire coil. This failure was caused by the beryllium wire seizing to a tacky plastic surface of the reel. It was found that this condition was due to a reaction between the plastic and a solvent accidentally splashed on the surface of the reel.

The starting material for the third run was supplied by the rear half of the first coil that resulted from the break at 0.002053-inch die size of the first run. This run featured a 20:1 dilution of the standard lubricant (Acheson Dag 206) and the cleaning and inspection procedures

TABLE I

WARM DRAWING RESULTS FOR ULTRAFINE WIRE

	1st Run	2nd Run	3rd Run
Material Heat No.	2-6295	2-6295	2-6295
Nominal Die Size	Start 0.00477 inch x 50 feet	Start 0.00477 inch x 50 feet	
0.00453	OK	OK	
0.00429	OK	OK	
0.00407	OK	OK	
0.00386	OK	OK	
0.003663	Broke 16 feet from end	OK	
0.003475	OK	OK	
0.003297	OK	OK	
0.00313	OK	OK	
0.002967	OK	Broke at Capstan Lost 1/3	
0.002815	OK	OK	
0.002671	OK	OK	
0.002534	OK	OK	
0.002404	OK	OK	
0.002281	OK	OK	
0.002164	OK	Tensile breaks -Scrap-	Start 0.002164 inch x 50 feet from 1st Run
0.002053	Broke in half		OK
0.001948	Broke in half		OK
0.001848	Broke at rear		Tension break on take-up spool and on capstan
0.001753	OK		OK
0.001663	Broke in half		Furnace breakdown -lost 3 points and broke at rear.
0.001578	Broke in half		Broke in half
0.001497	-Scrap- Unable to point		Broke in half from handling
0.001420			OK
0.001347			Broke up

mentioned earlier. Although a tension break occurred between the capstan and take-up reel on the 0.001848-inch diameter pass, the first four passes are considered successful. The furnace breakdown during the 0.001663-inch diameter pass rather clouds the draw results of the next pass. It is felt that the break occurring at 0.001578-inch die size may have been initiated on the preceding cooler pass. Improper handling again broke the wire at the 0.001497-inch diameter pass. The material failed completely at the 0.001347-inch die size.

C. Evaluation

Tensile tests were cut during the first and third drawing runs and the properties are reported in Table II. All tensile specimens were tested using a 2-inch gage length with a 0.1 in./in./min. strain rate. The specimens were in their "as-drawn" condition.

TABLE II

SOME MECHANICAL PROPERTIES OF BERYLLIUM ULTRAFINE WIRE (2-6295)

Specimen No.	Drawn Diameter[a] (inches)	Reduction Ratio From Last Anneal	Tensile (Room Temperature) Ultimate[b] ($\times 10^3$ psi)	Yield[c] ($\times 10^3$ psi)	Elong.[d] %
RI-2756	0.0036	295 to 1	168.5	141.5	0.70
RI-2757	0.0036		182.7	131.6	2.79
RI-2770	0.0036	Last anneal	181.7	142.4	1.77
RI-2771	0.0036	0.062 inch	183.2	139.3	4.09
RI-2772	0.0036	diameter	182.7	145.4	2.05
RI-2773	0.0036		182.5	143.4	2.35
RI-2774	0.0036		182.7	142.0	2.78
RI-2775	0.0036		165.0	144.7	0.55
RI-2776	0.0036		181.7	140.7	4.08
RI-2758	0.00281	486 to 1	186.5	134.6	2.10
RI-2759	0.00281		184.7	135.1	1.56
RI-2777	0.00281	Last anneal	187.4	141.9	1.98
RI-2778	0.00281	0.062 inch	186.6	141.7	1.48
RI-2779	0.00281	diameter	183.3	134.6	1.56
RI-2780	0.00281		185.7	144.4	2.30
RI-2781	0.00281		185.6	139.0	1.97
RI-2782	0.00281		180.3	140.0	1.25
RI-2783	0.00281		184.7	141.2	1.69
RI-2858	0.001578	1540 to 1	200.4	167.2	0.57
RI-2859	0.001578		189.2	166.7	0.42
RI-2860	0.001578	Last anneal	171.8	169.2	0.21
RI-2861	0.001578	0.062 inch	169.8	166.2	0.23
RI-2864	0.001578	diameter	190.2	164.6	0.46
RI-2865	0.001578		202.0	186.1	0.50
RI-2867	0.001578		166.7	144.2	0.38
RI-2868	0.001578		138.1	122.7	0.48
RI-2869	0.001578		199.4	160.6	0.70
RI-2870	0.001578		165.2	161.1	0.22

[a] The drawn diameter value was considered equal to the specified die diameter and was used in the calculations of the tensile ultimate and yield strength values.

[b] Ultimate strength is computed by dividing the maximum load by the area corresponding to the "specified die diameter".

[c] Yield strength is computed by dividing the yield load (at 0.2% offset) by the area corresponding to the "specified die diameter".

[d] Elongation was graphically measured on the load-deformation curve.

III. DISCUSSION AND FUTURE PLANS

Reviewing the results of the first three draw runs, the failures center between the 0.002 and 0.001347-inch-diameter sizes.. The major problem of correct handling procedures increases in difficulty as the wire becomes smaller. However, with the noted improvement in success between the first and third draw runs, it is felt that this problem will be considerably minimized with additional experience.

The preliminary tensile data for Lot No. 2-6295 shown in Table II do not indicate improved properties over those obtained for 0.00477-inch diameter wire reported earlier.[2] Also, the wide spread of values obtained from the 0.001587-inch diameter wire may indicate a plateau of strength regardless of size. The low tensile results of some of the beryllium specimens would tend to give unfavorable drawing results, and probably explains part of the breaking difficulty experienced at the 0.001578-inch diameter and at 0.001347-inch diameter of the third run.

Future plans include additional drawing runs using Lot No. 2-8842. One coil starting at 0.010-inch diameter, having its last anneal at 0.062-inch diameter, is now in process. It is planned to test this material at the following levels; 0.10, 0.005, 0.004, 0.003, 0.002 inch, and extensively in the neighborhood of 0.0015-inch diameter. The chemical analysis of Lot No. 2-8842 is listed in Table III.

It is also planned to remount the present take-up reel assembly and use it as the capstan after the wire is under 0.002-inch diameter. This change will decrease the handling of the wire to a minimum and should eliminate much of the trouble experienced to date.

TABLE III

CHEMICAL ANALYSIS OF LOT NO. 2-8842

Element	% by Weight
Be	98.38
BeO	1.64
C	0.12
Al	0.06
Fe	0.124
Mg	0.05
Si	0.025

IV. REFERENCES

1. A. G. Gross, Jr., R. G. O'Rourke, and W. W. Beaver, "Fabrication of Beryllium Wire", Final Report for Navy Contract NOas-59-6030-c, November 28, 1959.

2. A. G. Gross, Jr., R. G. O'Rourke, and W. W. Beaver, "Fabrication of Beryllium Fine Wire", Final Report for Navy Contract NOas 60-6108-c, April, 1961.

3. E. A. Murphy, A. G. Gross Jr., R. G. O'Rourke, "Fabrication of Ultrafine Beryllium Wire", Bimonthly Report No. 1 for Navy Contract NOw 63-0137-c, March, 1963.